Sampling Aerosols on the International Space Station

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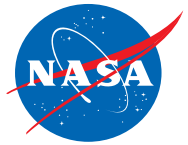


Outline

- Background
  - Previous aerosol sampling experiment in space
  - International Space Station
- Aerosol Sampling Experiment
  - Objectives
  - Two Samplers
    - Thermophoretic
    - Passive
- Summary

Definition

Aerosols are tiny particles suspended in the air.

Aerosols in Earth's atmosphere include pollution, smoke, dust, pollen as well as particles from many other natural and man-made materials.

We breathe in aerosols all day long.

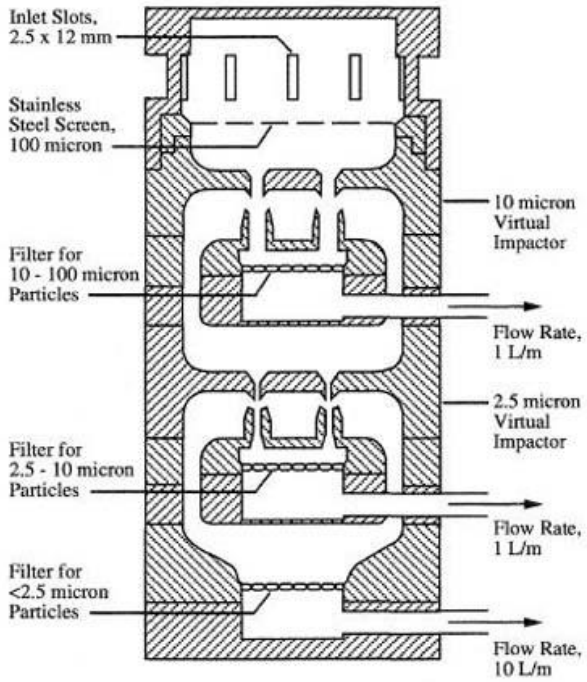
Aerosol Measurements on Space Shuttle

- Instruments developed at the University of Minnesota
- Space Shuttle Columbia experiments 1990 and 1991

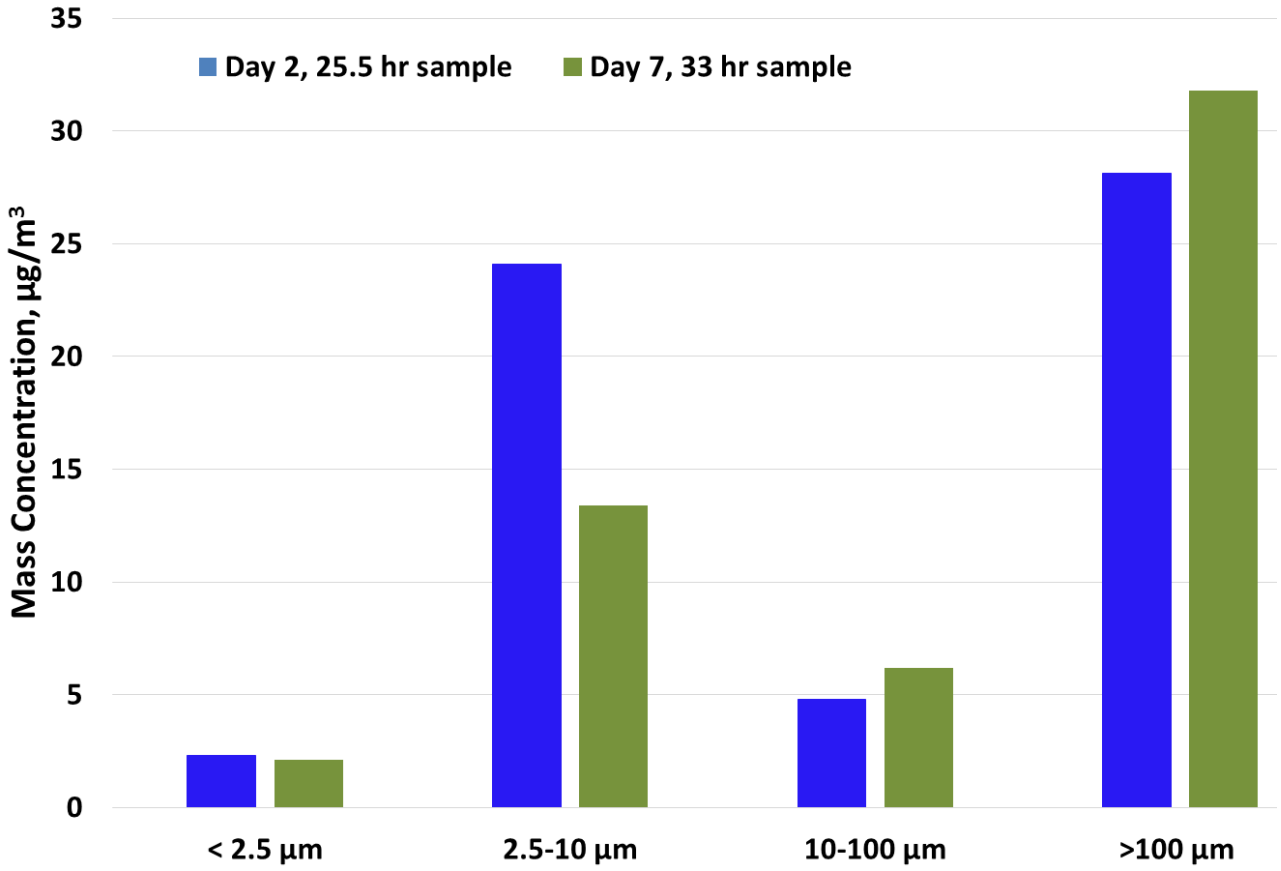
Aerosol Measurements on Space Shuttle

- Shuttle Particle Sampler (SPS) – Multi-stage impactor and filtering system for size distributions, XRF & microscopy

- Shuttle Particle Monitor (SPM) – Real-time Nephelometer (photometric detection of scattered light) for time-resolved mass concentration



- 5 people on STS-32 Columbia
- 71.5 m^3 Habitable Volume
- Sampled day 2 and 7 of the 11 day mission

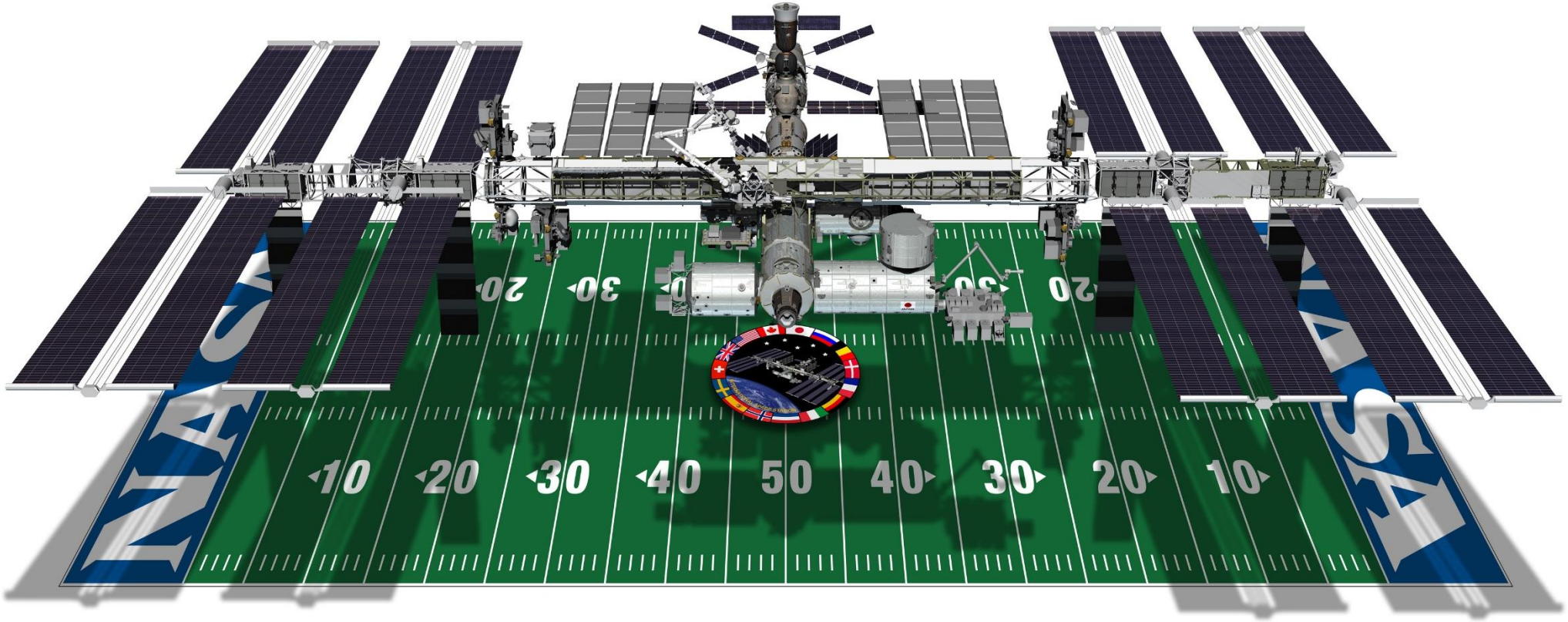


- Average concentration: 56 µg/m3
- ***'Clean' by indoor air quality standards***
- No measurements < 1 µm

- Space Shuttle retired in 2011
- Data no longer useful

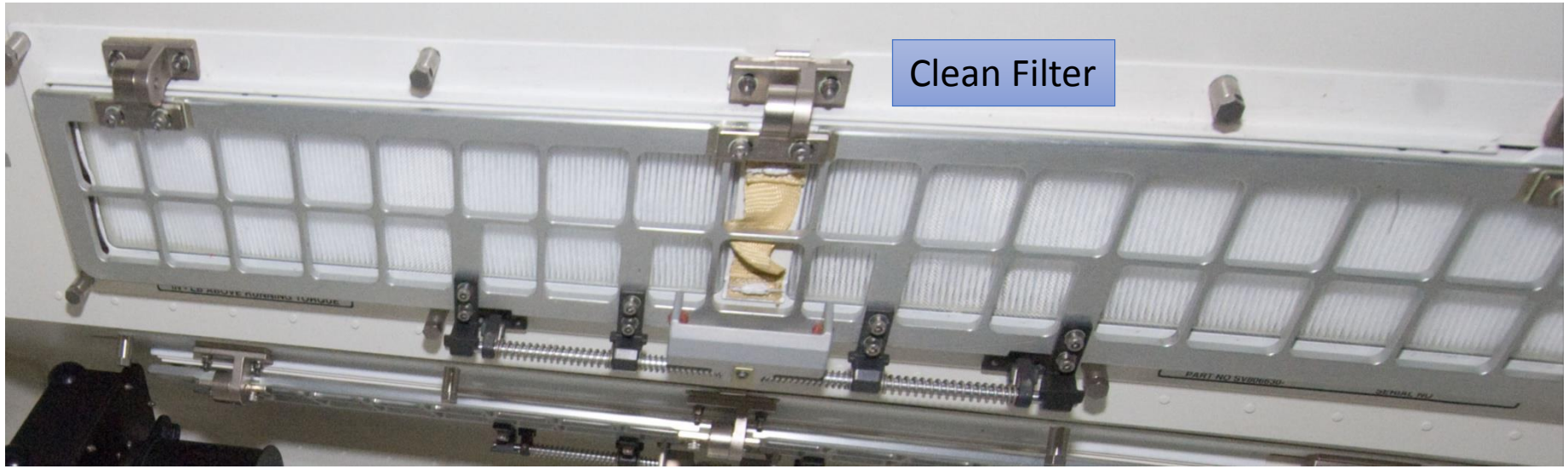
International Space Station (ISS)

- 388 m^3 Habitable Volume
- Continuously occupied for 14 years
  - 225 people from 18 countries, typically 6 crewmembers at a time



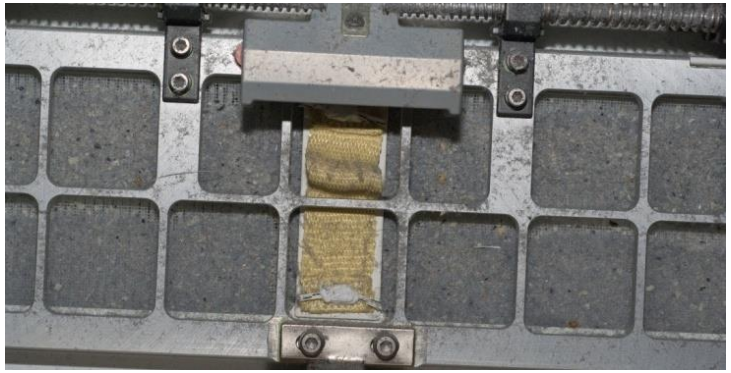
Aerosols on ISS

- On Earth, our air quality is improved by gravitational settling of large partices
  - On ISS, all particles remain airborne until deposited on surfaces or on filters of the air handling system
- ‘Dusty air’ has been a recurring complaint of the crew
  - Nose and eye irritation, allergies
  - Indicates high concentrations of inhalable particles



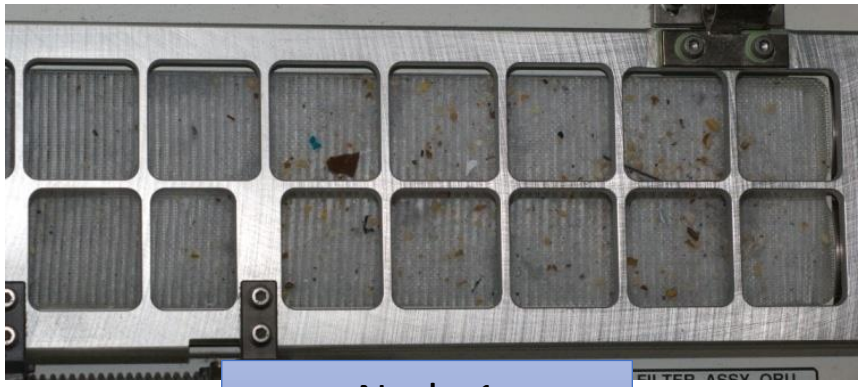
12 days accumulation

Node 3
Hygiene & Exercise
Location



8 days accumulation

8 days accumulation



Node 1
Temporary Storage
Location

Weekly chores on ISS

Aerosols on ISS

- Aerosol mass concentration requirements exist
- There is currently no particle measurement capability on ISS

- Estimated inventory of aerosols on ISS
  - Literature review - aerosol emission rates associated with common activities
  - Forensic analysis of returned ISS vacuum bag and ISS filter returned
  - Fabric testing


SDTO
LOW IMPACT DOCKING SYSTEM
LIDS
INTERNATIONAL SPACE STATION
HUMAN RESEARCH PROGRAM
DIGITAL ASTRONAUT PROJECT
Thursday, March 20, 2014
Karen Nyberg Visit Agenda
Time | Topic | Location | POC
9:00 | CIR, FIR | Building 333, HiBay | Bob Corban
9:15 | TSC | Building 333, TSC | Kevin McPherson
9:30 | ECL, Harness | Building 110, HiBay | Gail Perusek
10:00 | Project Team Meetings | Building 77, Room 245
15 minutes each
• InSPACE-3 | Nang Pham
• CFE-2 | Bob Hawersaat
• ACE/LMM | Ron Sicker
• MDCA-FLEX, -ICE-GA | Mark Hickman
• SAMS | Kevin McPherson
• ISS Ambient Air Quality | Marit Meyer
11:30 Adjourn
ISS Research POC: Fred Kohl, (216) 820-8767 cell
Team photos with Karen Nyberg will be taken with each group following their discussion.
NASA Glenn Wireless Network
Structure and Dynamics of Bimodal Depletion Gels in Microgravity
P&G
SHARP
DO NOT UNPLUG ANY CABLES
ISS 2012 - Top Discoveries
In recognition of outstanding results on Cool Flames in Space

Aerosol Sampling Experiment

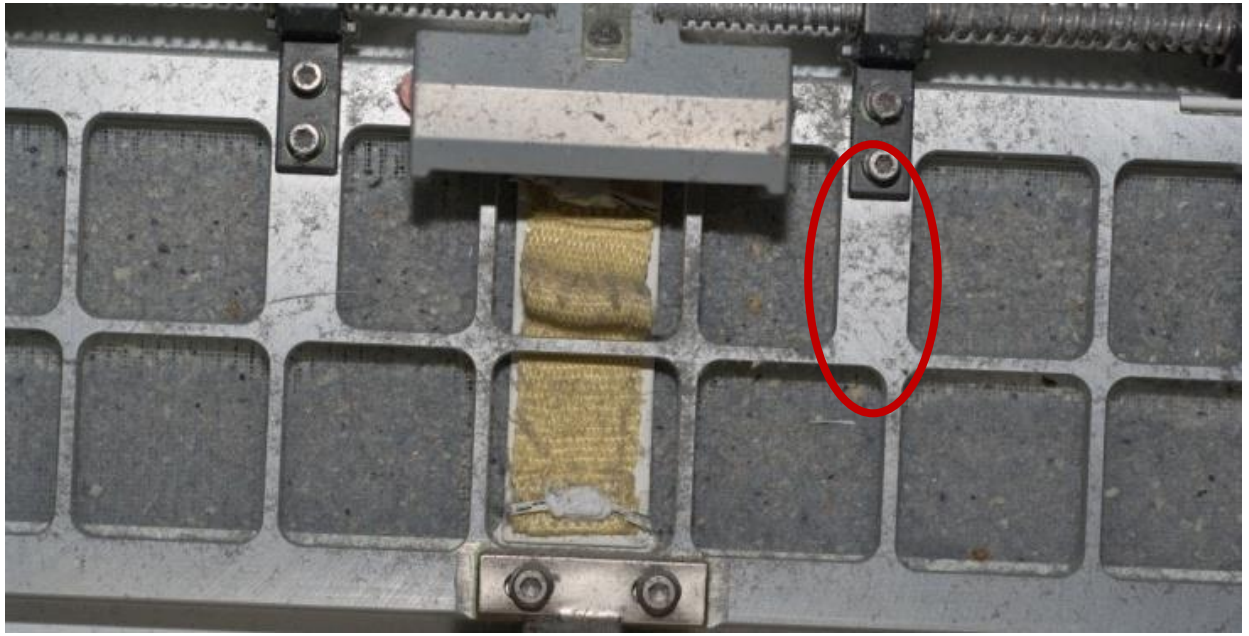
- Funded by NASA Advanced Exploration Systems Life Support Systems Project (AES LSS)
- Obtain ***quantitative*** data on airborne particles in multiple ISS locations and associated with different activities
- Sample particles and return to Earth for microscopic analysis
  - Simple experiment gives long-duration average data
  - Low cost and low risk
- Launches August 22 (in 1 week!)

Collect Airborne Particles on ISS

- Start with two different commercially available samplers
  - COTS = commercial-off-the-shelf hardware

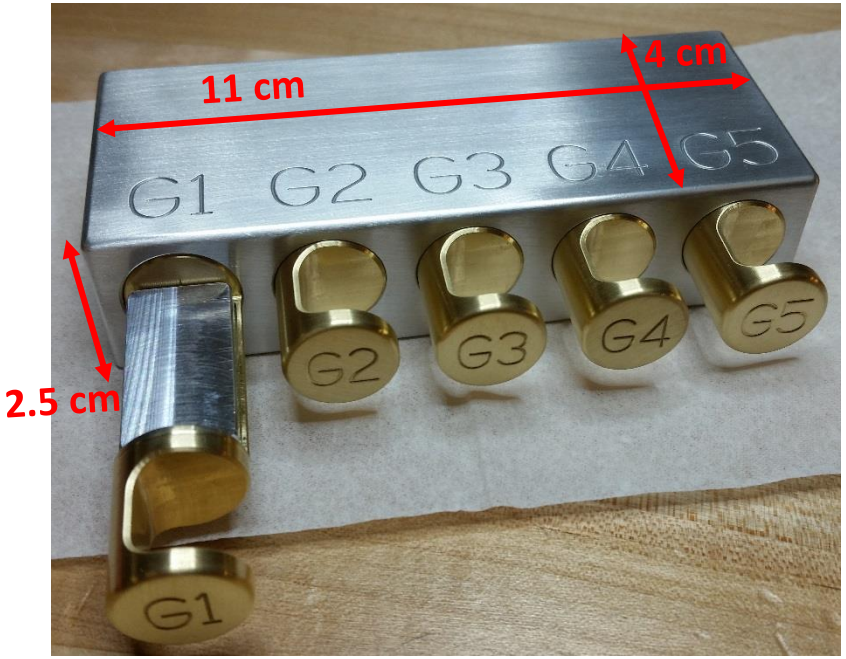
COTS Passive Aerosol Sampler (PAS)

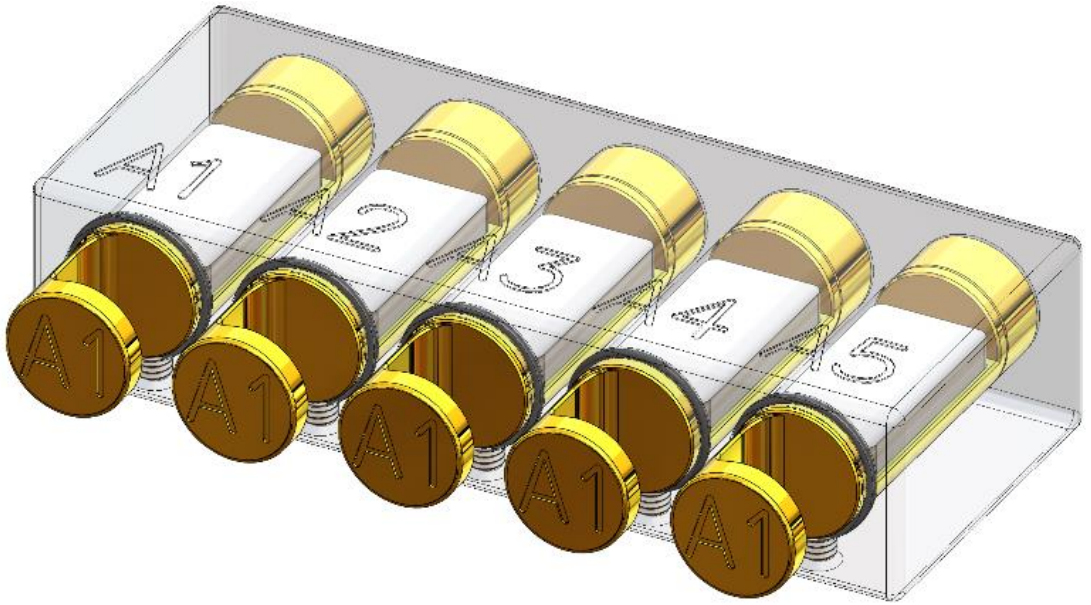
Collect particles up to 500 µm & larger



Passive Sampler

- Custom array of **passive** samplers



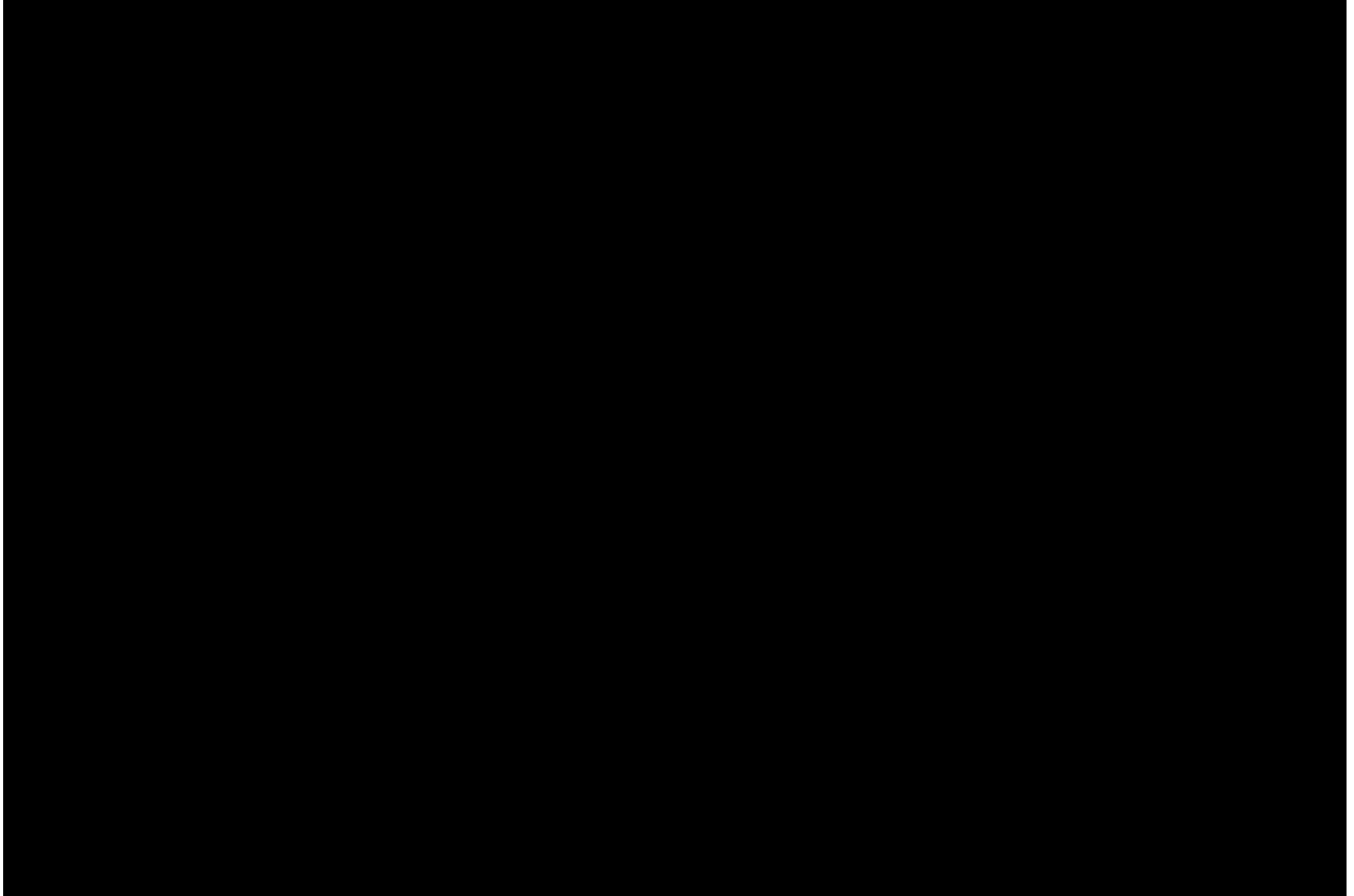


Collect particles up to 500 µm & larger

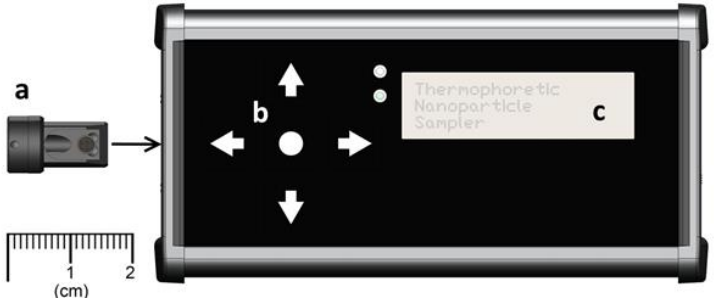
Deploy with drawers open for a month, close drawers on days 2, 4, 8, 16 and 32

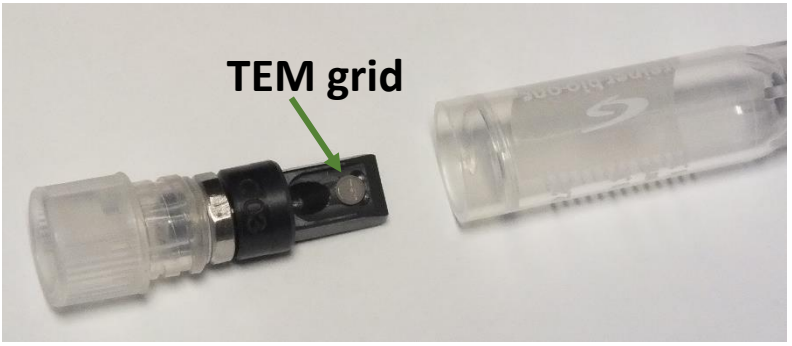
Crew Instruction Video

- NASA Marshall Space Flight Center Payload Operations Integration Center
- ISS US Lab mock-up in the Laboratory Training Complex
  - Simulation rooms used to prepare PAYCOMs for space station expeditions
    - (Payload Communications Manager)



COTS Thermophoretic Personal Sampler





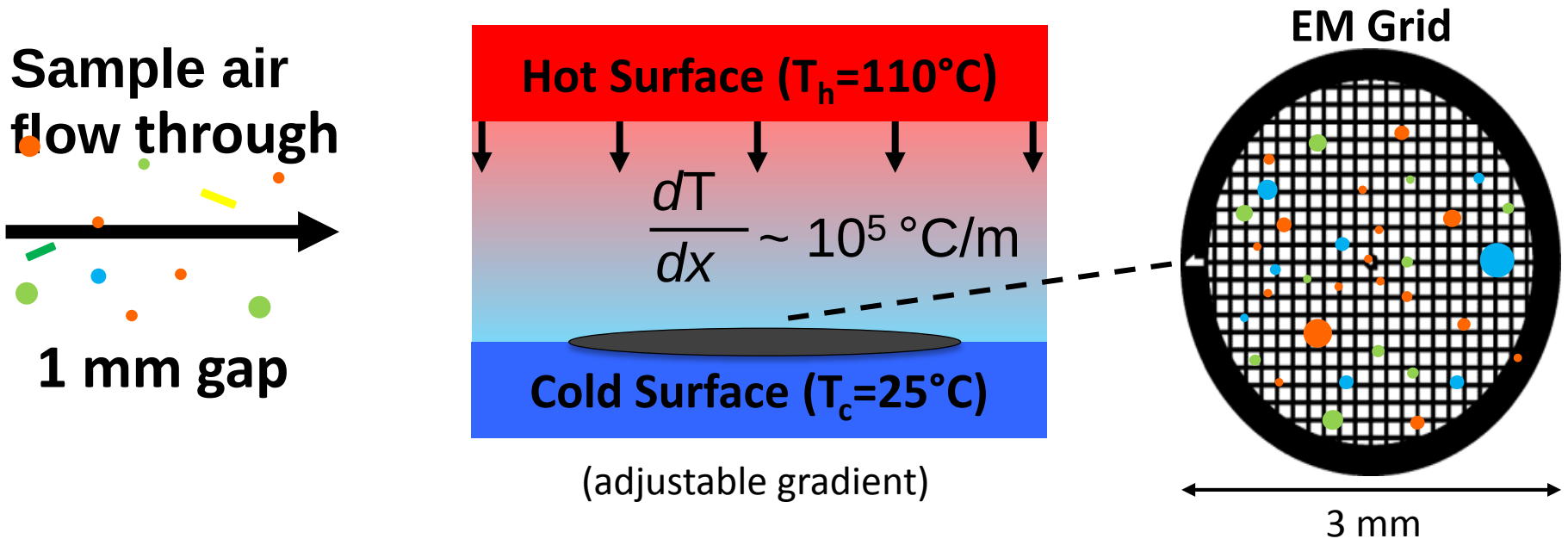
-small parts that can float away!

TEM =Transmission Electron Microscope

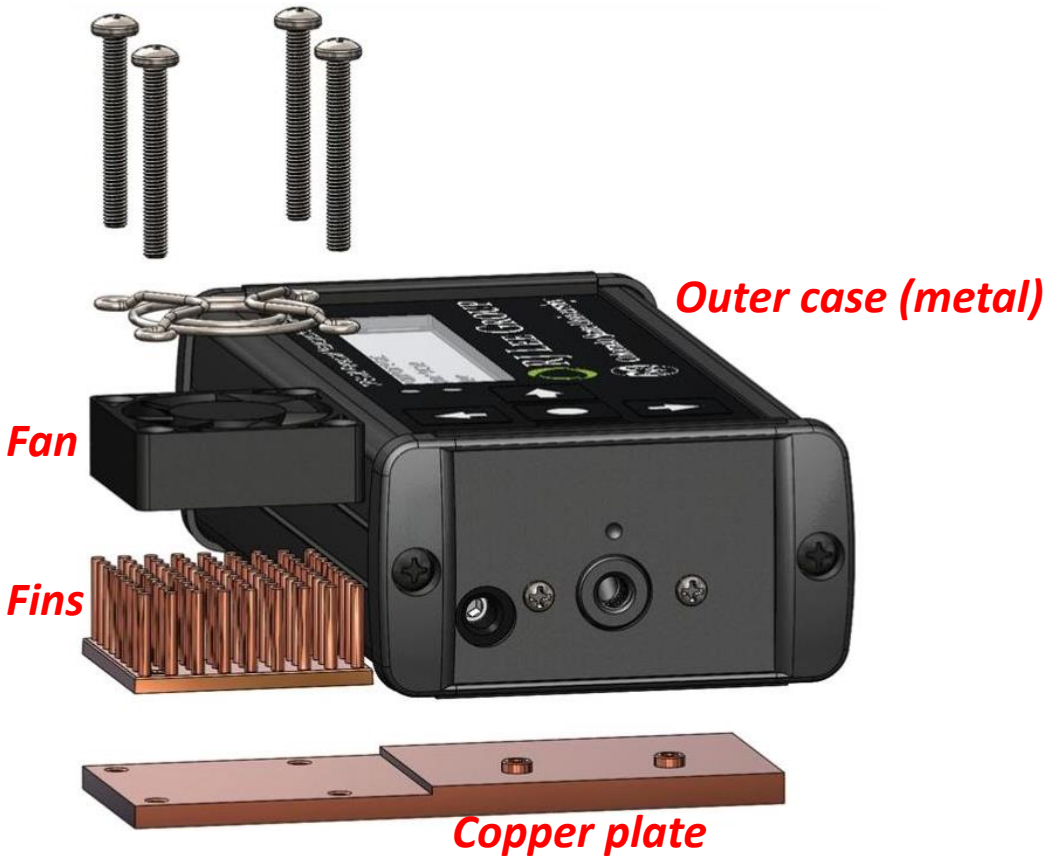
Active sampler:

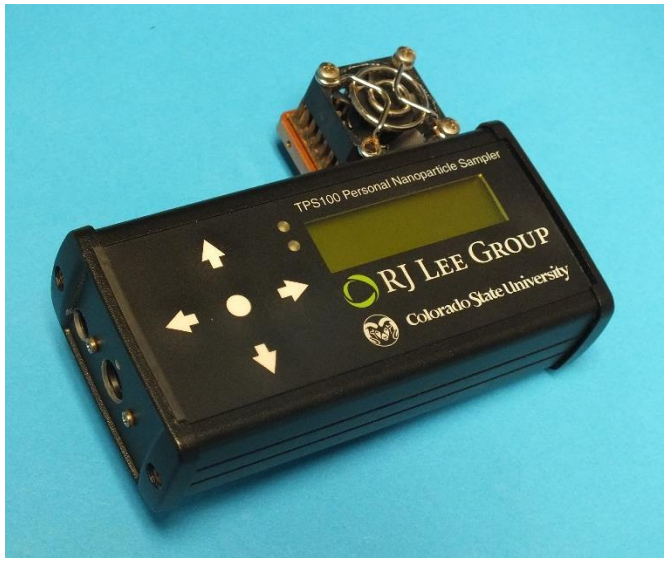
- **Contains pump, heater, cooler, circuit cards, battery**
- **Samples for 6 hours**
- **Collect particles from 10 nm to ~10 µm**

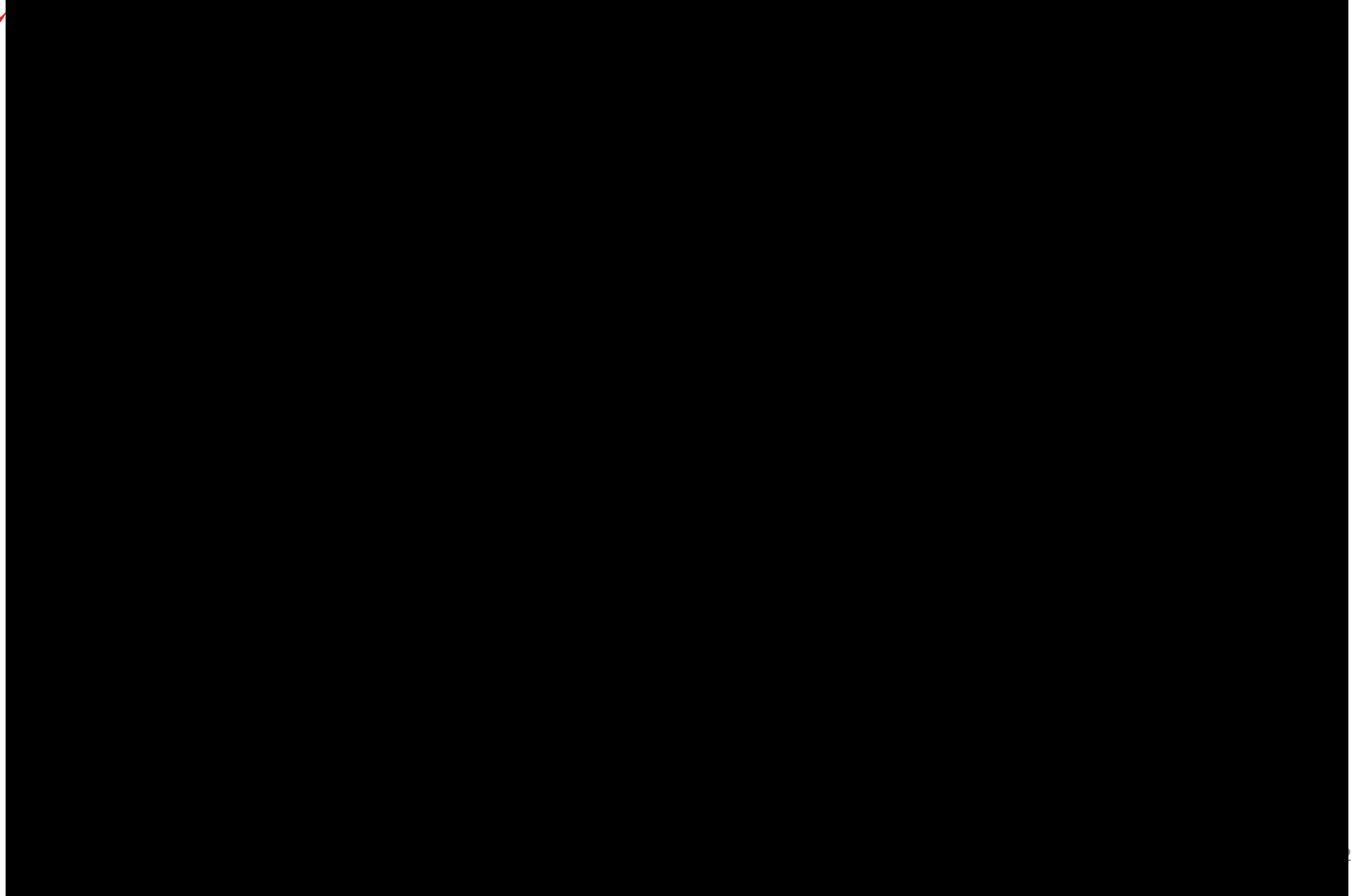
Thermophoretic Collection



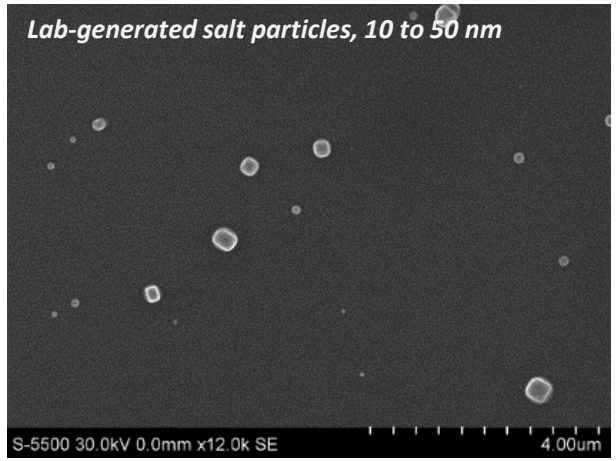
Thermal Modification of COTS Active Sampler

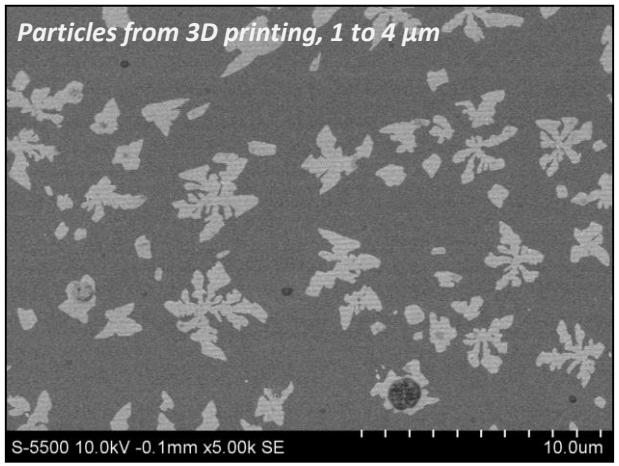


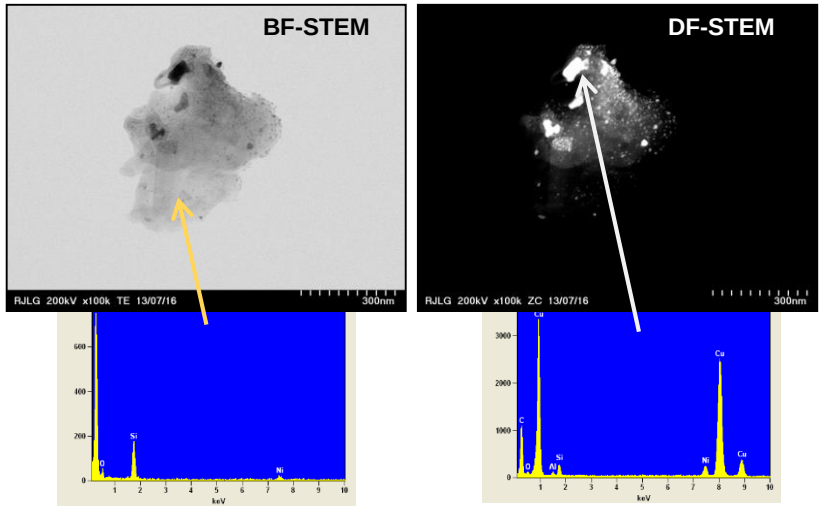




Example Data from Microscopic Analysis of Particles Collected by TPS







Two images of a particle from a small electric motor and the chemical compositions of different portions of the same particle

- Identify particle morphology
  - Shape
  - Coated or multi-component particles
- Chemical composition
  - Elemental speciation
- Potentially identify sources of individual particles returned from ISS
  - Lint from clothing
  - Skin flakes
  - Metal particles from exercise equipment
- Computer-generated particle size distribution

Sampling Locations

- 7 Passive sampler locations
  - Keep-out zone exceptions
- 12 Active sampler locations, 7 within 60 cm of passive samplers
  - During exercising
  - When a cargo vehicle arrives and docks to ISS
  - Hygiene compartment

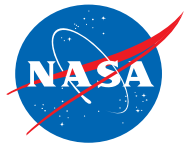
Summary

- Goal of sampling experiment is ***data:***
  - Validate inventory
  - Input for realtime instrument (stage 2 flight experiment)
  - Understanding background aerosol signature is important for the next generation smoke detector design

- Scheduled crew time mid-January to mid-February 2016
- Return samples to Earth to get results
  - SpaceX early March 2017
  - Contractor will perform the sample analysis (microscopy)
- Results will ultimately improve air quality in spacecraft
  - Fundamental for future long-term manned space missions

ISS015E17168

Questions?



Backup Slides

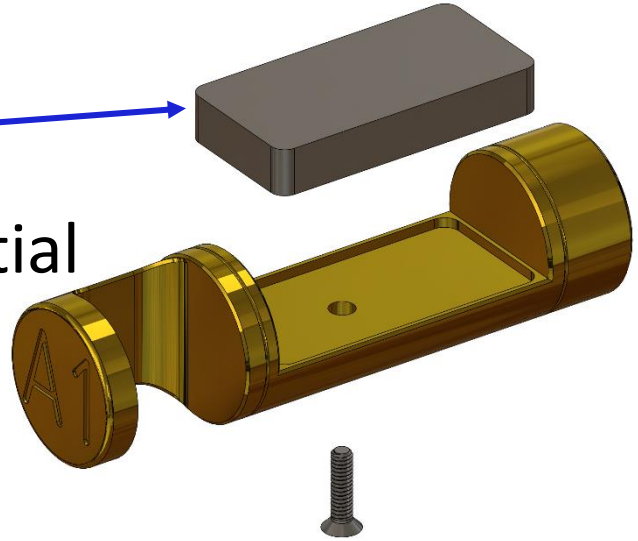
General Specifications (Original COTS)

Total weight	320g
Sampler Dimensions	122mm x 63mm x 38mm
Sample Cartridge Dimensions (3mm Diameter EM Grid)	46mm x 18mm x 15mm
Battery Duration (from full charge)	~8 hours
Charging Time	<3 hours
Battery Lifespan	>300 complete charge/discharge cycles
Recommended Hot Side Temperature Range	85 to 120°C
Recommended Cold Side Temperature Range	25 to 35°C
Volumetric Flow Rate	5 mL/min

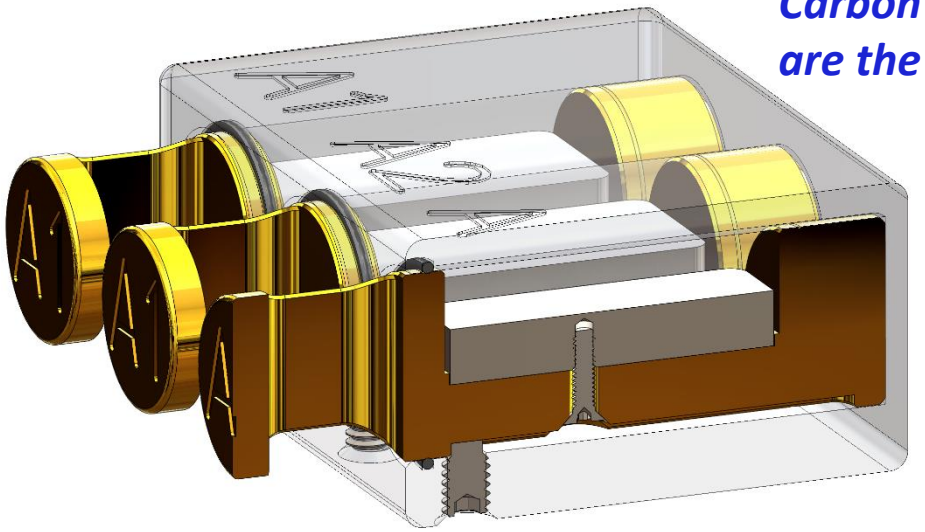
- Thermal Testing by RJ Lee Group:
  - When TPS was insulated (eliminating the benefit of natural convection) the outer case exceeded 40 ^{o} C touch temperature
- Absolute temperature control guarantees optimal sampling
  - If the large thermal gradient is not maintained (if waste heat is not eliminated from the internal thermo-electric coolers), the TPS will shut down

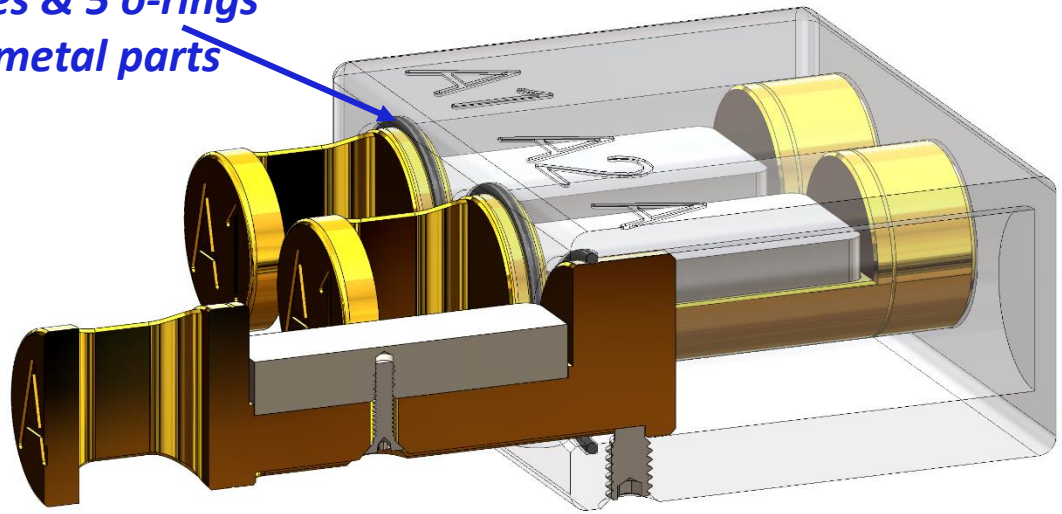
Passive Sampler

- 2-way sticky carbon tape on 29 mm x 15 mm collection surface (aluminum block)
- Collection plate samples can be archived for potential future analysis
- Units can be cleaned and re-used with a new aluminum block

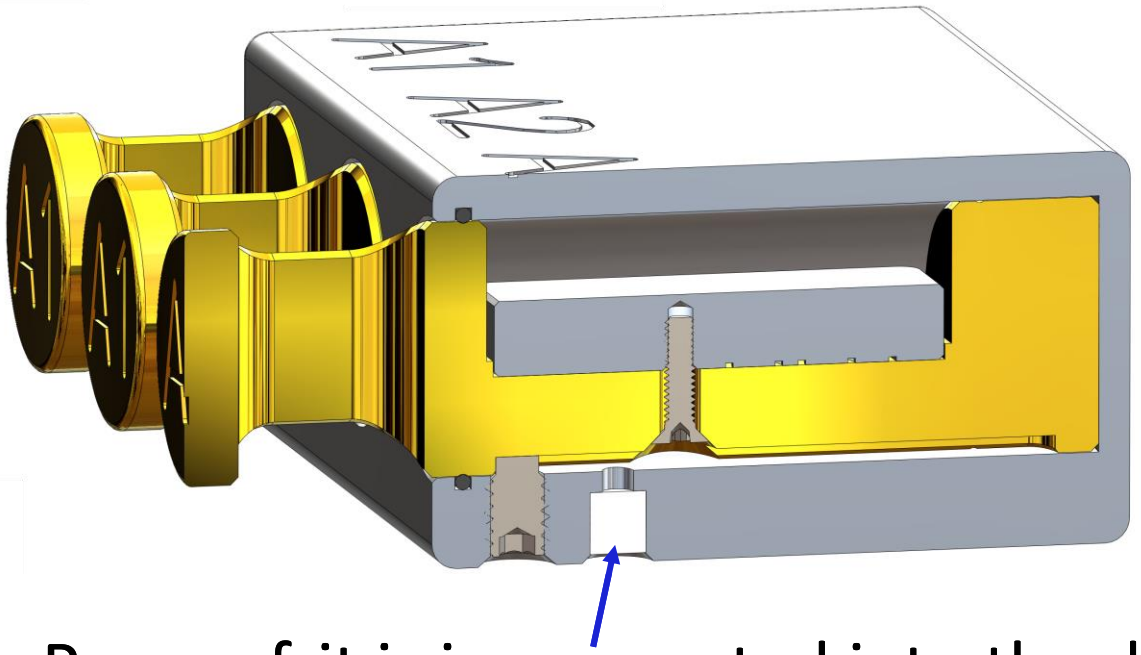


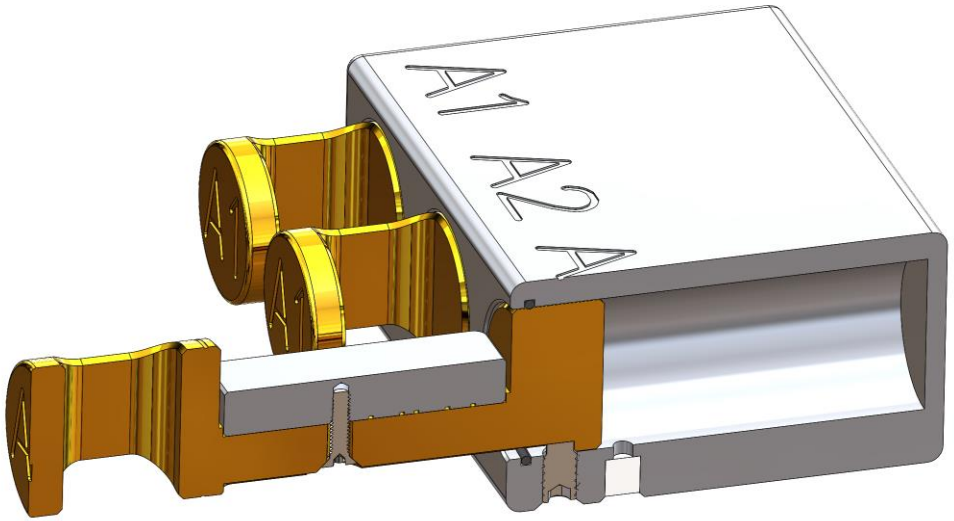
Carbon tape pieces & 5 o-rings are the only non-metal parts





Passive Sampler





- Porous frit is incorporated into the design to relieve the very small delta pressure that may occur when closing drawer
  - Will not allow particles in which could contaminate the sample